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Improved Understanding of the Modeled QBO using MLS Observations and MERRA Reanalysis

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Introduction

- The Quasi-Biennial Oscillation (QBO) dominates variability of the tropical stratosphere (Baldwin et al., 2001).
- In addition to the primary, a secondary circulation is formed by the QBO.
- It has been shown to impact the concentrations of many trace gas species (Dunkerton, 2001).
- Trepte and Hitchman (1992) showed that the secondary circulation of the QBO could be seen in observations of aerosol concentrations.
- Can we use observations from MLS and MERRA reanalysis to improve our understanding of the modeled QBO?

It is necessary to quantify the impact of natural variations of the climate system in order to more effectively isolate signatures of climate change. This is especially import when working with datasets that are sub-decadal scale.

Model and Measurements

Goddard Earth Observing System Chemistry-Climate Model (GEOSCCM)

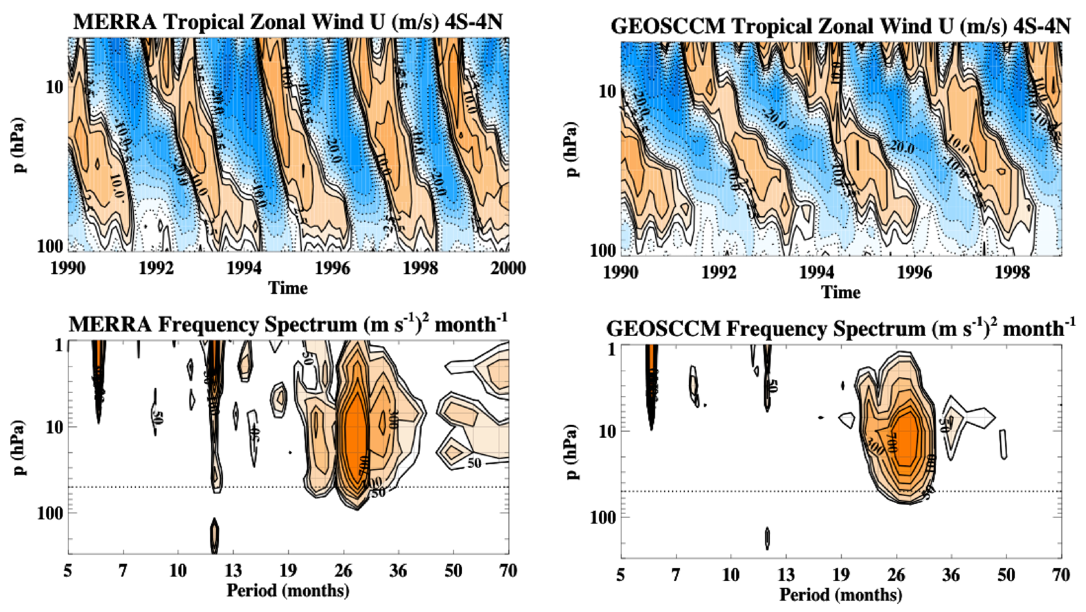
We used the combined GMI stratosphere-troposphere (StratTrop) chemical mechanism at 2° x 2.5° horizontal resolution with 72 vertical layers and an internally generated QBO.

This Time Slice 2005 simulation was forced with observed sea surface temperatures from 1985-2009 but fixed in time natural and anthropogenic emission sources for 2005.

We used observations from NASA's AURA Satellite and products from the Modern Era-Retrospective Analysis for Research and Applications (MERRA).

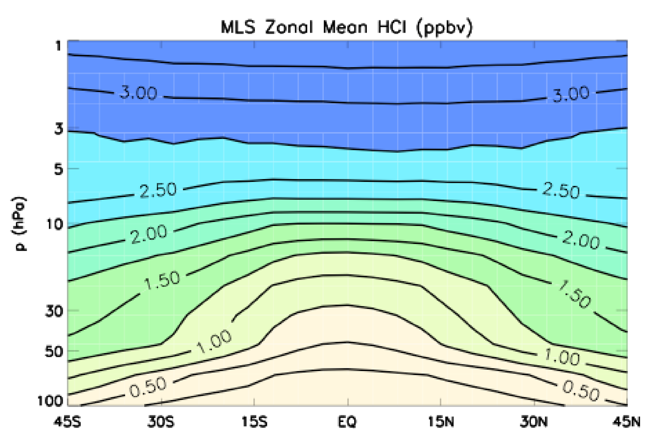
Microwave Limb Sounder (MLS) Level 2 Version 3.3 Aug. 2004 – Dec. 2012
MERRA Reanalysis – Jan. 1979 – Dec. 2012

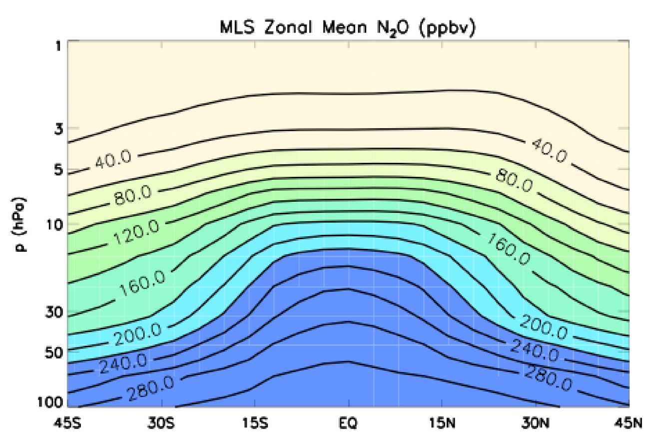
Using Frequency Spectrum analysis we can estimate the magnitude and periodicity of the modeled QBO and compare to MERRA reanalysis.



MLS Observations of HCl and N_2O

The figures below show the annual zonal mean climatology of HCl (ppbv) and N2O (ppbv) from observations taken with the MLS instrument. These trace gas species have different horizontal and vertical gradients which can highlight different areas of the circulation response to the QBO. Also, their different atmospheric lifetimes play a role in their response.





Multiple Linear Regression

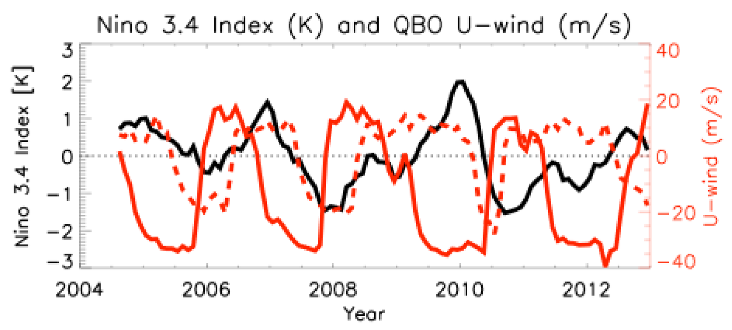
$$\Delta Var(t) = \sum_j m_{X_j} \Delta X_j(t) + \varepsilon(t),$$

ΔX are the changes in the different quantities

X_j are the different quantities that could influence a variable like the Niño 3.4 Index, QBO at 20 hPa, and QBO at 50 hPa

$m_X = \partial Var / \partial X$ are the sensitivities of a variable to the quantity of interest

ε is the residual in the fit



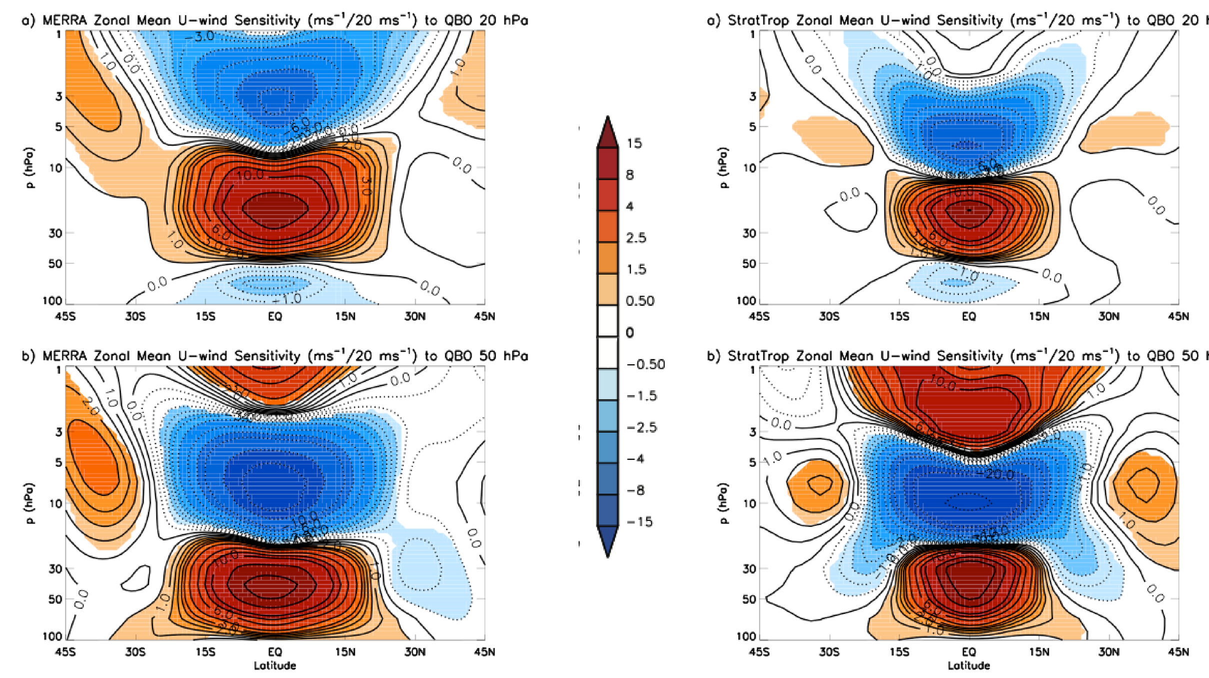
U-wind response to the QBO

Using multiple linear regression the variable of interest was deseasonalized before regressing against the QBO at 20 and 50 hPa (very similar to the first 2 EOFs of the QBO) and the Niño 3.4 Index. The U-wind response to the QBO is shown below and is useful for evaluating how well the width of the QBO is being simulated. On the left hand side is the response derived from MERRA reanalysis and on the right is the modeled response from GEOSCCM. The width of the model generated QBO is a bit narrower in the low to mid stratosphere. The color shading is significant above 2 SD.

MERRA GEOSCCM

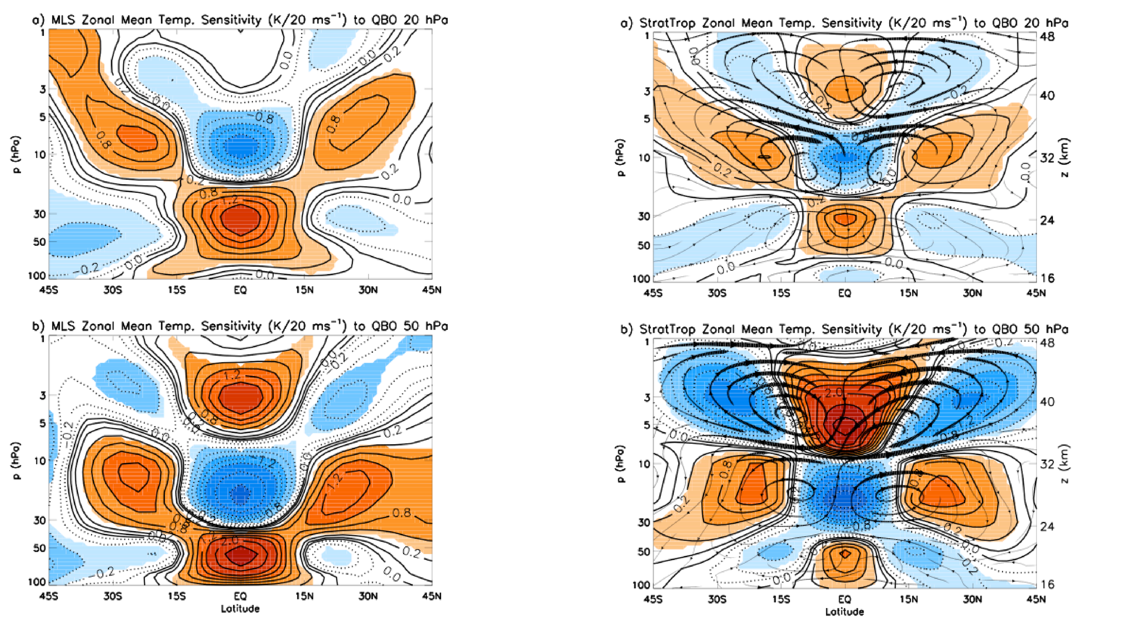
20 hPa

50 hPa



Temperature Sensitivity to the QBO

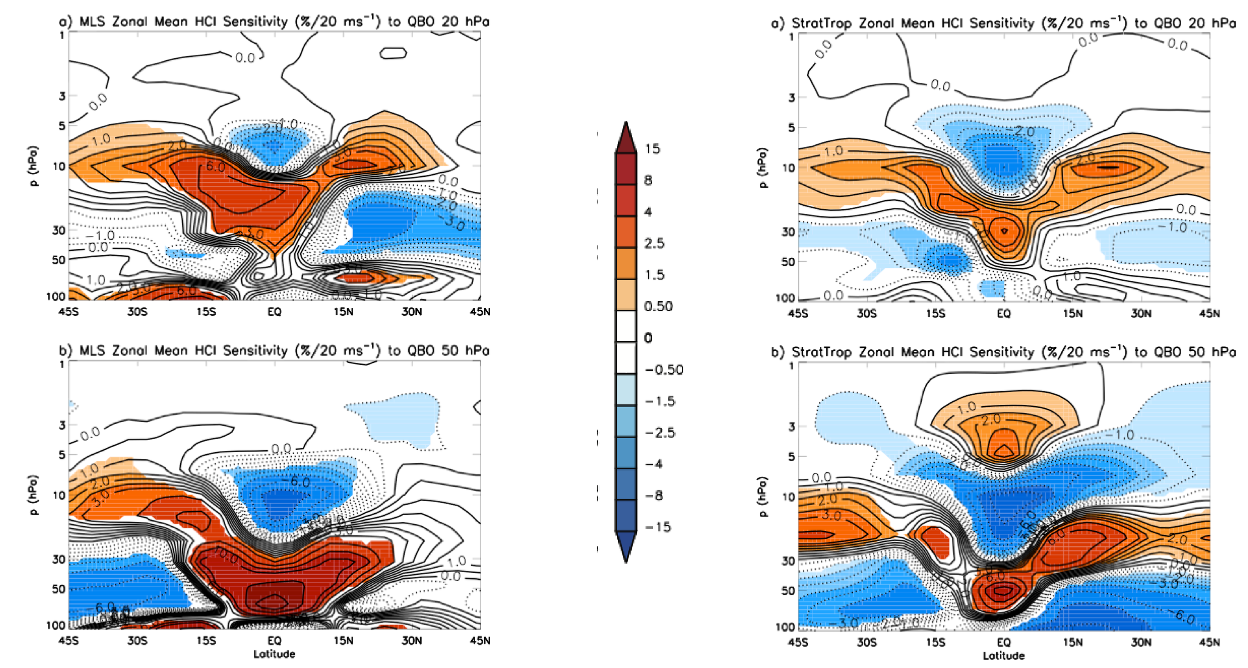
The temperature response to the QBO is shown below and represents the changes in vertical velocity from MLS (left panels) and GEOSCCM (right panels). Positive temperature sensitivities show areas of anomalous downwelling and negative temperature sensitivities show anomalous upwelling. The resulting streamlines are derived for the modeled response on the right hand side which shows the secondary circulation induced by the QBO. While the average response shown hear considers all months the response outside the deep tropics is seasonally locked to the Brewer-Dobson circulation causing the anomalies to be roughly twice as large in the winter hemisphere and near zero in the summer hemisphere.



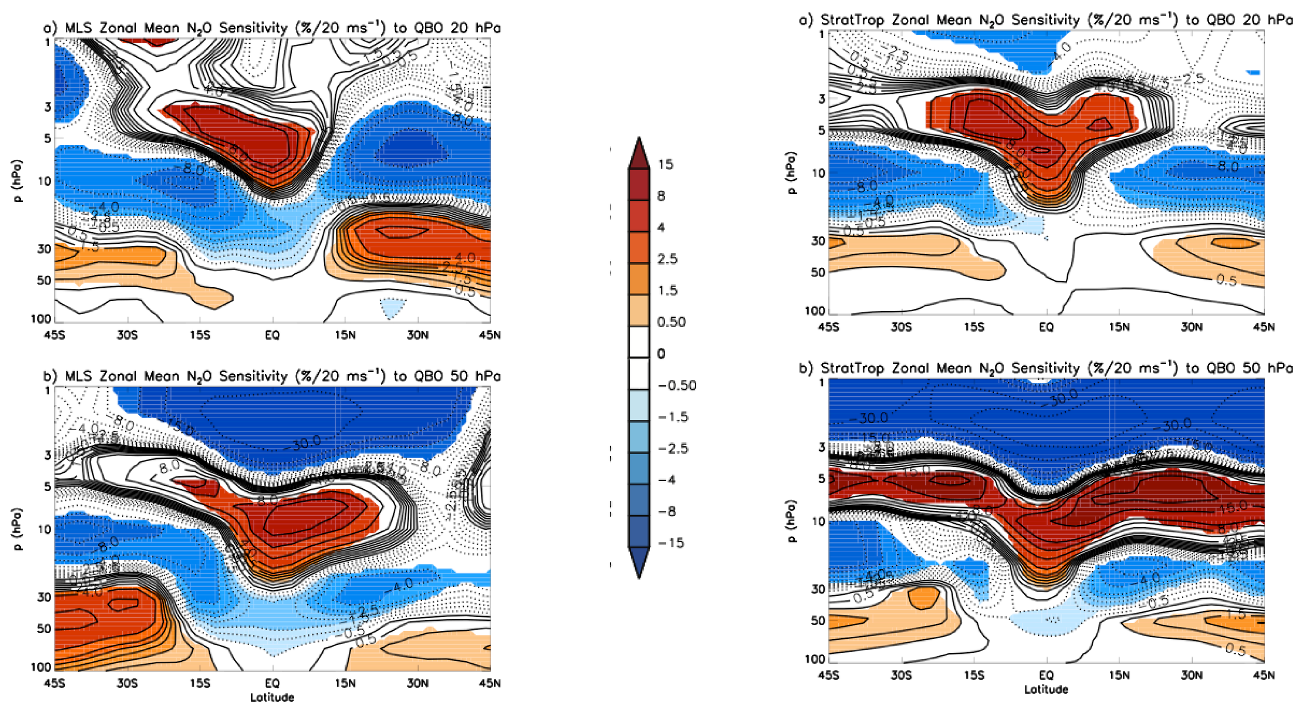
HCl and N_2O Response to QBO

The figures below shows the HCl sensitivity to the QBO derived from MLS (left panels) and GEOSCCM (right panels). The secondary circulation response changes the distribution of trace gases like HCl with a similar response pattern in the model as seen in observations.

MLS GEOSCCM



The N_2O response can be seen in the figures below for MLS (left panels) and GEOSCCM (right panels). The horizontal and vertical gradients are opposite those of HCl which causes the response to by of opposite sign as well. Differences in the atmospheric lifetimes between the two species can also be seen in the response.



Conclusions

- GEOSCCM can reasonably well reproduce the observed magnitude and periodicity of the QBO.
- The secondary circulation is evident in several trace gas species in observations and simulations.
- Some areas could use additional attention with sensitivity studies including the width of the simulated QBO and its magnitude in the lower stratosphere.
- Could test refining the non-orographic GWD forcing function as well as sensitivity to horizontal resolution.

Acknowledgements

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References

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